Brute-force, Dictionary Attacks and Mitigation

João Bettencourt

Fakulteta za elektrotehniko, računalništvo in informatiko, Univerza v Mariboru
Email: joao.bettencourt@um.si

The increasinng volume on digital systems in the modern society has increased the importance of security measures. One of the most persistent threats to digital security is the brute-force and dictionary attack, which exploits weak passwords to be harmful to systems. This paper explores these attack techniques, their mechanisms, and their impact on the modern society. By understanding the key points behind brute-force and dictionary attacks, we can identify vulnerabilities in password systems and propose effective mitigation strategies. This topic was chosen due to its significant relevance in today's digital age, where establishing security standards and practices is essential for protecting sensitive information. The study also emphasizes the need for stronger authentication methods and awareness to protect against evolving attack techniques. By combining theoretical analysis with practical demonstrations using tools such as Kali Linux, this work aims to highlight not only the risks posed by these attacks but also measures to improve digital security.

Keywords: Brute-Force Attacks, Dictionary Attacks, Password Security, Cybersecurity.

1. INTRODUCTION

Password-based authentication remains one of the most common methods for system security, based on their simplicity and effiency. However, it continues to show significant vulnerabilities, facing brute-force and dictionary attacks. Those methods exploit the inherent weaknesses of user-created passwords, which are often short, predictable and based on common patterns. In spite of decades of research and development of numerous countermeasures, the human factor remains the weakest link in the security trifecta.

By the new advancements in computational power, these vulnerabilities got aggravated, making attackers more effient cracking passwords. A task that used to require days now takes seconds or even less. At the same time, passwords cracking techniques have become progressively sophisticated, including vast dictionaries, permutations, and adaptive algorithms. These developments highlight the critical need for powerfull mitigation strategies that not only address technical vulnerabilities but also focus on improving user practices

This study investigates the mechanics of brute-force and dictionary attacks, demonstrates their effectiveness using practical experiments, and evaluates their strengths and weaknesses of most commonly used mitigation strategies. By analyzing passwords, by their entropy and characteristics, this work aims to emphasize the importance of adopting strategies to mitigate these attacks, by adopting stronger password policies and multi-factor authentication methods.

2. EXECUTION OF THE ATTACKS

This study was conducted using Kali Linux, one of the most known linux distributions, usually used in cybersecurity. The tool used for these attacks was Hydra, an extremely verstaile and efficient password-cracking tool that supports a wide range of protocols. Hydra operates by taking wordlists and generating password combinations, with the objective of cracking the target system. This system was configured to test password combinations against a brute-force attack, displaying the vulnerabilities of weak password systems. The attack was executed on a login system with weak security measures, exemplifying how easily attackers can gain unauthorized access to systems.

Hydra Configuration Brute-Force

- Target Protocol: HTTP POST form
- Command Example for BruteForce:
- -l admin: Specifies the username.
- -x 4:8:a: Instructs Hydra to generate all alphanumeric combinations between 4 to 8 characters.
- http-post-form: Defines the protocol and the login endpoint.
- F=invalid: Indicates the failure message in the login response.

Hydra Configuration: Dictionary Attack

To execute a dictionary attack using Hydra, the following configuration was used:

- **Target Protocol:** HTTP POST form
- **Wordlist:** `rockyou.txt`
- **Command Example:**
- **Explanation of Parameters:**
  - `-l admin`: Specifies the username.
  - `-P /path/to/rockyou.txt`: Points to the dictionary file.
  - `http-post-form`: Indicates the target protocol and login endpoint.
  - `F=invalid`: Defines the failure message to detect unsuccessful attempts.

2.1. Brute-force Approach

Brute-force attacks usually involve a trial-and-error approach used to gain acess to unauthorized systems, attempting every possible password combination until finding the correct one. This method is is methodical and guarantees success if there are enough time and resources available, making it an essential technique in cyberwarfares. The complexity of the attack depends on the character set and length of the target. By including uppercase and lowercase letters, numbers, special symbols and other characters, the number of potential combinations increases exponentially, prolonging the time required for a successful attack. While Brute-force attacks are elementary in theory, their effectiveness is often limited by pratical components, such as time, computational power, or security measures like account lockouts after several failed attempts. Nonetheless, attackers can bypass these limitations using distributed networks of computers, most know as botnets, or leveraging advanced tools like GPUs for faster computations. Brute-force attacks are commonly used in specific scenarios, such as bypassing login systems, cracking encrypted files, or retrieving Wi-Fi passwords. Although they are less efficient than more targeted methods, like dictionary attacks, brute-force attacks are essential for testing password security and identifying vulnerabilities in systems. Despite that, this attack remains one of the most critical strategies for gaining unauthorized access to systems, making it a significant threat to digital security.

Scenarios

Usually there are some scenarios where brute-force attacks are more likely to be used, such as:

- Breaking Into Accounts
  - Attacker, most of the time, targets online accounts by systematically guessing login credentials. Systems without a proper defense are particularly vulnerable, such as lockout mechanisms or multi-factor authentication (MFA).
  - Brute-force can focus on a specific account, often using information about the user to guess probable passwords.
  - Bots may attempt to brute-force large number of accounts on systems with weak password policies, with the objective of gaining unauthorized access.

- Decrypting Files
  - Encrypted filesm are another target for brute-force attacks. Encryption, when relies solely on a user-defined password, causes a huge risk for systems, as attackers may attempt to use this for their advantage.
  - Files secured by weak our outdated encryption methods have a higher risk of being cracked.
  - Since the attacker has direct access to the encrypted file, they can particularly work without being detected by the file's owner.

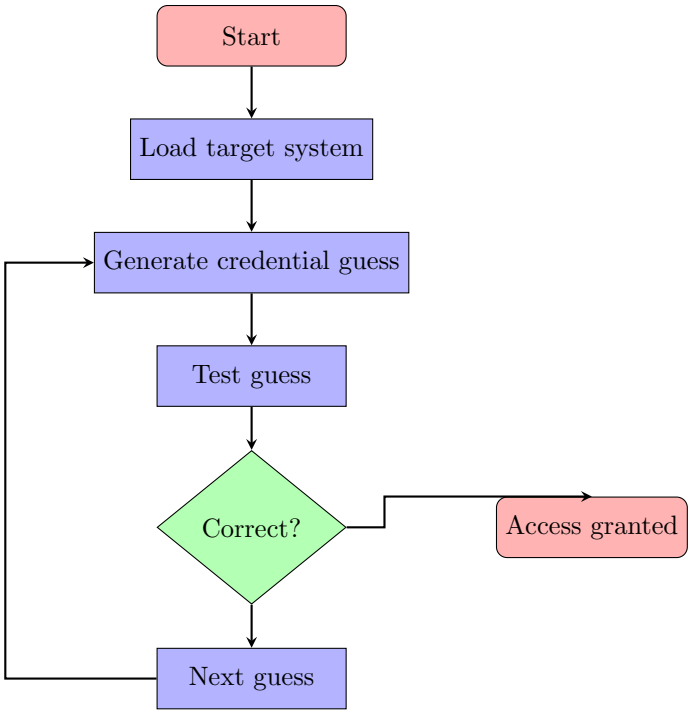
Tools

Brute-force attacks often require specific tools built to efficiently try countless password combinations. Most widely know tools:

- Hydra
  - Highly verstaile and efficient password-cracking tool
  - Supports a wide range of protocols, HTTP, FTP, SSH, MySQL, SMTP, and more.
  - Operates by taking wordlists and generating password combinations and systematically trying them against the target.

- John the Ripper(JTR)
  - Optimized for speed and support a variety of hasing algorithms, such as MD5, SHA, and bcrypt
  - Hash focused.
  - Widely used for reasearch and testing password strength in operating systems, databases, and other applications.

2.2. Brute-Force Attack Process Flowchart

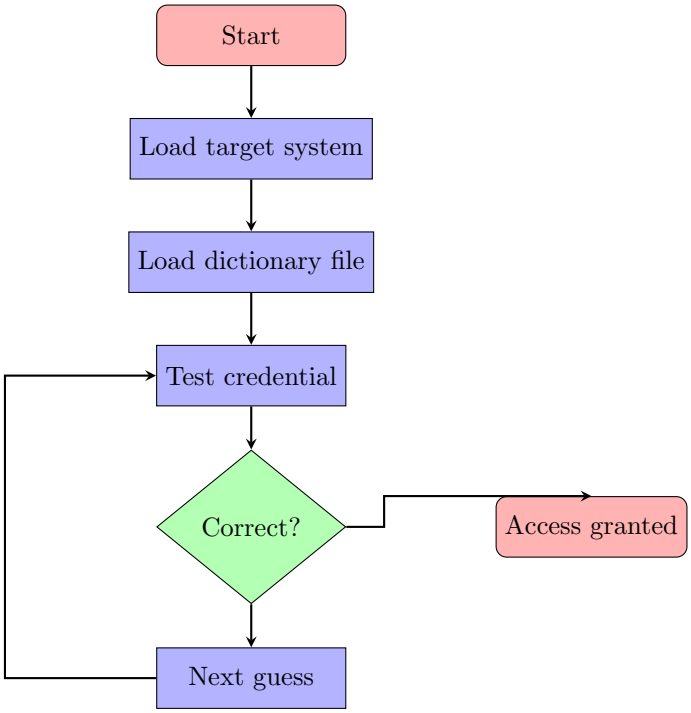


2.3. Dictionary Approach

Dictionary attack is a method of attacking cybersecurity that relies on a pre-established list of potential passwords, most known as a "dictionary". Unlike brute-force attacks, dictionary attacks focus on the assumption that the password is weak and common. This method peaks in effiency when users choose simple passwords based on common words, phrases or patterns.

Aspect	Brute-Force	Dictionary
Speed	Slow, tests all combinations.	Faster, skips unlikely combinations.
Coverage	Comprehensive, guarantees success if time permits.	Limited by dictionary size and quality.
Assumptions	No assumptions needed about the password.	Assumes password is common or predictable.
Efficiency	Inefficient for long, complex passwords.	Efficient for weak or common passwords.
Customization	Difficult to target specific users.	Can be tailored for specific users.
Defense	Strong passwords and lockout mechanisms.	Unique and complex passwords help.

2.4. Dictionary Attack Process Flowchart



2.5. Methodology

Methodology...

3. ANALYSIS

Analysis of what was done before

4. MITIGATION STRATEGIES

Mitigation strategies are measures implemented to reduce and banish risks from cyber threats, such as brute-force and dictionary attacks. The main goal is to protect sensitive systems, accounts and data while making sure legitimate users have their accessibility secured. The strategies are essential for the modern world, where attackers are increasingly using revolutionary methods to exploit vulnerabilities.

- Prevention: MFA and password salting make attacks more difficult by increasing complexity;
- Detection: Captcha and monitoring detect suspicious activities;
- Response: Account lockouts limit the impact of ongoing attacks

4.1. Account Lockouts

Account lockout mechanisms are a security methods designed to restrain brute-force attacks by temporarily disabling accounts after a pre-agreed number of failed login attempts. This proceeds towards limit the number of guesses an attacker can make, by that means reducing the likelihood of unauthorized access. Nevertheless, while efficient mitigating brute-force attacks, they can

still be exploited to launch denial-of-service (DOS) attacks, making legitimate useres unable to access their accounts. Research highlights that attackers can intentionally trigger account lockouts.[1] To make the security and usability in homeostasis, it is recommended to implement adaptive lockout policies that consider factors such as the user's typical behavior and the context of the login attempts. For instance, the Open Web Application Security Project (OWASP) suggests that while accounts are in lockout stage, they can prevent brute-force attacks, they should be configured to minimize the risk of being leveraged for DoS attacks [2] In conclusion, account lockout policies are a must have tool in defending against brute-force attacks but must be carefully configured to avoid unwanted consequences, such as DoS.

4.2. Captcha

CAPTCHAs, Completely Automated Public Turing tests to tell Computers and Humans Apart, are commonly used to distinguish human users from bots, thereby mitigating automatic attacks such as brute-force login attempts. By handing over challenges that are easy for humans but difficult for machines, CAPTCHAs can block bots from completing password guesses. However, CAPTCHAs are not absolute on the prevention of those attacks. Studies have shown that particular CAPTCHA systems, mainly those with low complexity or predictable patterns, can be vulnerable to automatic solving strategies. [3] As wel, the usability of CAPTCHAs is a critical consideration. The complexity of CAPTCHA can frustrate legitimate users, leading to a negative user experience, and can also make the system vulnerable. Therefore, while CAPTCHA can serve as a brake on brute-force attacks, balacing security needs with user accessibility. On top of that, CAPTCHAs should not be used as single and high-handed security measure, other methods should be used at the same time to provide a more robust security. [4]

4.3. Multi-factor Authentication

Multi-factor authentication most known as "MFA"enhances security by requiring useres to provide more than one form of verification, usually 2 to 3 ways of verification, before accessing a system. By combining something the user knows, something they have, or something they are, MFA adds layers of protection that forbid unauthorized access. Research indicates that implementing MFA can block over 99.9% of account compromising attacks, including brute-force and dictionary attempts.[5] Within the frame of brute-force attacks, where attackers widely attempt various password combinations to gain unauthorized acess, MFA serves as a tough brake. Even if an attacker is sucessfull guessing a password, the aditional verification factors required by MFA, prevent unauthorized entries. This multi-layered system ensures that the compromise of a single factor does not grant access, thus significantly enhancing security.[6] For that reason, adopting MFA is a crucial strategy to mitage risks associated with brute-force attacks, ensuring that only authorized userss can access sensitive systems and informations.

4.4. Password lenght

Password lenght is a critical factor to defend against brute-force attacks, where attackers can attempt multiple times all possible to estimate a password. The longer the passwords the longer it takes to be deciphered, increasing the number of potential combinations. Refering to a study analyzing real-world passwords found that shorter passwords are more receptive to brute-force attacks. with over 11% of them being cracked. [7] In addition , research indicates that a significant portion of compromised passwords are under 12 characters, suggesting that increasing password lenght can improve resistance to these attacks. [8] For that reason, enforcing longer password policies is an effective strategy to mitage the risk of digital break-ins.

4.5. SALT

Salting is a securtiy method that consists in adding a unique, random value as a šalt"to each user's password before hashing. This procedure guarantees that even identical passwords result in distinct hash outputs, mitigating efficiently the risk of precomputed attacks such as rainbow tables. By embracing salts, attackers are compelled to compute the has for each password attempt individually, notably increasing the computational effort required for a successful attack. Research indicates that salting, when hashing, empowers password security by preventing attackers from leveraging precomputed hash databases. [9] Besides, studies have exhibiting that salting, when hashing, provides strong defense against dictionary and brute-force attacks. The addition of salt to passwords increases the complexity of the hashed output, making it more challenging for attackers to crack passwords using pre assembled tables and systems. [10] For that reason, salting techniques are fundamental practices in enhancing password security and protecting against unauthorized access.

4.6. Monitoring and Server Logs

Monitoring server logs is a critical element in defending against brute-force attacks. By analyzing logs, administrators can expose patterns that indicate such attacks, being able to block and prevent unauthorized access. Server logs are a valuable resource for identifying and responding to security threats. Regular monitoring of Logs can help detect unusual patterns,

such as a high number of failed login attempts or multiple accounts targeted in a short period. These anomalies often indicate brute-force attacks. Real-time log analysis tools can provide insights into ongoing attacks, leading administrators to take immediate action to block malicious actors. For example, monitoring SSH logs can help detect and block brute-force attacks in real-time, preventing unauthorized access to systems. [11] Moreover, monitoring server logs can help identify vulnerabilities in password systems, such as weak passwords or outdated authentication methods. Research on brute-force attack patterns in IoT networks demonstrates that time-sensitive statistical analysis of log data can uncover attack strategies, informing the development of more robust defenses.[12]

5. CONCLUSION

LITERATURE

[1] Account Lockouts: Characterizing and Preventing Account Denial-of-Service Attacks *Worcester Polytechnic Institute and Oak Ridge National Laboratory*, https://web.cs.wpi.edu/~cshue/research/securecomm.19.lockouts.pdf.

[2] Blocking Brute Force Attacks *Esheridan*, https://owasp.org/www-community/controls/Blocking_Brute_Force_Attacks

[3] Practicality analysis of utilizing text-based CAPTCHA vs. graphic-based CAPTCHA authentication *Spring Nature Link*, https://pmc.ncbi.nlm.nih.gov/articles/PMC10152023/.

[4] CAPTCHA Types and Breaking Techniques: Design Issues, Challenges, and Future Research Directions *Cornell University*, https://arxiv.org/abs/2307.10239

[5] How effective is multifactor authentication at deterring cyberattacks? *Cornell University*, https://arxiv.org/abs/2305.00945.

[6] Multi-Factor Credential Hashing for Asymmetric Brute-Force Attack Resistance. *Cornell University*, https://arxiv.org/abs/2306.08169v1.

[7] Password Cracking with Brute Force Algorithm and Dictionary Attack Using Parallel Programming *MDPI*, https://www.mdpi.com/2076-3417/13/10/5979

[8] Do longer passwords protect you from compromise? *specops*, https://specopssoft.com/blog/longer-passwords-protect-compromise/

[9] Analysis of Password and Salt Combination Scheme To Improve Hash Algorithm Security *TheSai*, https://thesai.org/Downloads/Volume10No11/Paper_58-Analysis_of_Password_and_Salt_Combination_Scheme.pdf.

[10] Enhancing Salted Password Hashing Technique Using Swapping Elements in an Array Algorithm *ResearchGate*, https://www.researchgate.net/publication/352312164_Enhancing_Salted_Password_Hashing_Technique_Using_Swapping_Elements_in_an_Array_Algorithm.

[11] Realtime Risk Monitoring of SSH Brute Force Attacks *ResearchGate*, https://www.researchgate.net/publication/361105775_Realtime_Risk_Monitoring_of_SSH_Brute_Force_Attacks.

[12] Investigating Brute Force Attack Patterns in IoT Network *Journal of Electrical and Computer Engineering*, https://onlinelibrary.wiley.com/doi/10.1155/2019/4568368.